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BENEFITS ASSESSMENT OF WATER POLLUTION CONTROL IN
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**Benefits Assessment of
Water Pollution Control in Ontario**

A Proposal

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**Benefits Assessment of
Water Pollution Control in Ontario**

A Proposal

Prepared for

**Fiscal Planning and Economic Analysis
Ontario Ministry of the Environment**

by

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July 19, 1991

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1.0 Introduction

The government of Ontario and private industry have spent substantial amounts of time and money to protect the interests of the people of Ontario from the pollution of Ontario's waters. The Remedial Action Plans (RAP) for selected Areas of Concern and the Municipal and Industrial Sewage Abatement (MISA) program are large-scale examples of these efforts. These pollution control programs and others are targeted toward pollutant levels equivalent to zero discharge levels throughout Ontario. The goal of zero discharge in Ontario is ambitious and needs continued substantive financial commitment from the public of Ontario and private industry. A clear understanding of the benefits of these programs is critical for the continuation of these commitments.

Despite the need and desire for this level of pollution control, understanding of the public benefits that are derived from these control programs is scant and difficult to obtain. The Ministry of Environment, which works with the public and private industry in the development of these pollution control programs, needs to know more accurately the public benefits of these programs. This information is critical for the evaluation of the efficacy of existing water pollution control programs, the allocation of limited funds to these control programs, and the development of new programs. In particular, the ministry needs to be able to assess the potential effectiveness of different levels of pollution control at different locales with respect to derived public benefits. Both retrospective, *ex post* analyses of the public benefits of ongoing programs and *ex ante* analyses of future benefits from new or expanded programs are needed. This information will help justify the continuation of current pollution control programs, and will provide the rationale for new or modified programs.

The assignment described by the ministry in the request for proposals (RFP) will provide the ministry with a computational tool to assist ministry analysts in assessing the public benefits of water pollution control. ESSA Ltd. has gained substantial experience in developing tools of similar nature (which we refer to as Decision Support Systems, DSS) for a variety of clients responsible for environmental management. For this particular assignment, we have assembled a project team with both the disciplinary expertise and experience needed in developing such frameworks. We believe that the approach and workplan we provide in this proposal will lead to the development of a high quality product that will meet the essential needs of the ministry.

2.0 Objectives

The objectives of this project as stated in the RFP are:

1. Develop automated, comprehensive, well documented computational procedures that can be used to explicitly identify, quantify and, where possible, value the public benefits of water pollution control and abatement programs and activities, *ex post* and *ex ante*; and
2. Collect necessary data and produce empirical estimates of *ex post* and *ex ante* incremental benefits and their associated values for specific control or abatement levels for industrial and municipal wastewater dischargers at specified sites, water bodies or regions.

Our understanding of the second of these two objectives is that it will be met through the acquisition and consolidation of existing data; in particular, that new collections of "field" data will not be required. This does not preclude the estimation of model parameters or coefficients to be derived from existing data sets.

1.0 Introduction

The objective of this report is to provide a summary of the findings of the study.

The study was conducted in accordance with the requirements of the OMOE. The results of the study are presented in the following sections. The first section provides a summary of the findings of the study. The second section provides a detailed description of the study. The third section provides a summary of the conclusions of the study.

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3.0 Understanding and Approach

3.1 Linkages: Water Pollution, Human Activities, Health and Perceptions

The proposed project requires that the contractor develop "computational procedures that can be used to explicitly identify, quantify and, where possible, value the public benefits of water pollution control and abatement programs and activities .." Public benefits are those favourable impacts arising from the avoidance of future or the elimination of existing external environmental damages. Actions that produce these benefits may reduce the inputs of pollutants to a water body. Alternatively, they may affect the impairment indirectly by the removal or immobilization of in situ contaminants, or by manipulating other dimensions of a water body such as its flow regime. We can predict the affect of such measures through our understanding of basic principles of conservation, momentum and thermodynamics. This understanding is expressed mathematically in the form of fundamental or empirical relationships that describe the state and rate of change of systems (Environment Canada, 1976). There are a variety of models that combine mathematical relationships into system of equations that describe the dynamics of a water body and its related watershed. These range from simple statistical equations predicting the loading of sediments from crop lands to adjacent streams (e.g., Haith and Shoemaker, 1987) to complex systems of equations that provide a multi-dimensional simulation of water quality dynamics in a body of water (e.g., MacKay, 1987; Walker, Weatherbe and Wilson, 1982).

Perhaps the simplest types of relationships are mass balance relationships that describe the fate of conservative substances as they become diluted by mixing; although even simple mixing processes become complicated if one must delineate a mixing zone by accounting for the diffusion and conveyance of contaminants over time and space (Gowda, 1980). If the contaminant happens to partition between, say sediments and the water column, or if it is transformed by oxidation, reduction, or biological uptake and metabolism, the relationships required to describe their fate become considerably more complex. For instance the dissolved oxygen regime in a stream is mediated by photosynthesis, respiration, oxygen demand by organic pollutants and nitrogenous materials, dilution and gas exchange with the atmosphere. These in turn are affected by temperature, sunlight, wave action, water depth, plant nutrient concentrations and so on (Loucks, Stedinger and Haith, 1981). Under such circumstances, the prediction of the water quality outcome of a change in pollutant loadings (or flow) does not lend itself to simple analyses--the location, timing, duration, frequency and severity of impairments can all change as a result of a remedial action, and all of these changes may be significant in the evaluation of benefit.

A water modelling procedure that maintains a degree of fidelity to the system that it is meant to describe will feature equations describing the hydrology and hydraulics of the system, its chemical and possibly thermal processes, and basic biological processes that affect the rate of transformation of chemicals in the water column. Such a model will use pollutant loadings as inputs and will estimate the level of contamination that results from these loadings. However, this is only the first step in a chain of interrelated events that turn the chemical reconstitution of a natural body of water into an impairment of that water.

Impairment implies that values that we hold have somehow been depreciated. This depreciation arises because the water quality changes have affected the way in which we can or want to use water, or because of an altered perception of the intrinsic qualities of body of a water. In the Bay of Quinte RAP, impaired uses included swimming, boating, shoreline cottaging, municipal water supply, waterfowl hunting and sport and commercial fishing (Ecologistics Ltd with CH2M Hill Ltd, 1990). The full evaluation of just one of these impaired uses, say swimming, would involve the following analytic steps:

1. inventory of swimming areas, their use levels, and their degree of impairment,
2. assessment of current loadings and concentrations of pathogenic or indicator bacteria at impaired swimming areas,
3. identification and assessment of potential remedial measures to reduce or divert bacterial loadings to each area,
4. estimation of the impact of remedial measures on the concentration of bacteria (exceedances of criteria, frequency and duration of exceedances, absolute counts),
5. estimation of the resulting change in the number of beach closures over a summer period,
6. estimation of any pathogenic effects caused by existing and estimated loadings,
7. assignment of user values to changes in closures and/or changes of the incidence of infections.

In the evaluation of swimming for Quinte, Ecologistics was able to undertake specific analyses for steps 1, 2 and 7; data and information required for other steps was simply not available, so that assumptions were made to bridge the intervening steps. In a subsequent synoptic analysis, Apogee Research et al (1990) assumed their way directly to step 7. In a similar fashion, Sudar and Muir (1985) assign entire value of the Lake Ontario sport and commercial fishery as the cost of continued toxic waste loadings from Niagara sites without attempting to delineate a cause and effect relationship that would cause this fishery to lose all of its value within the stipulated 5 year time frame. Simplifications and gross reductions of this sort are not uncommon in water resource studies that attempt explicit evaluations of impacts. In part this reflects constraints on knowledge and information, in part the absence of explicit guidelines for benefit evaluation (in contrast to flood reduction planning--see MNR, 1983), and in part it reflects the nature and complexity of the water resource planning process (Fortin, 1989).

Key linkages in the chain of events that relate water quality to our value systems are the dose-response relationships that describe the degree of impairment, and value assignments that measure the importance to us of that impairment. Traditional water quality planning problems may involve dose-response relationships that link nutrient concentrations to the growth of nuisance aquatic weeds, algal densities to the occurrence of

taste and odour problems, or oxygen deficits to fish mortality. Risk assessments dealing with health effects use dose-response relationships that relate health risks to exposure to toxic or pathogenic substances. Kirkwood (1985) describes EPA's use of statistical linear cancer risk models to evaluate the risk of exposure to perchloroethylene. Seyfried and Brown (1985) have researched the relationships between the incidence of infections in swimmers and the exposure to water borne bacteria. But such dose-response information is as yet very incomplete and uncertain when dealing with many of the toxic compounds that are found in our waters (Grover and Zussman, 1985).

Conceptual approaches to assignment of value to environmental benefits have been exhaustively developed and argued by economists for several decades. Of particular interest to this study is the growing collection of research efforts that apply economic models to Ontario water resources. Evaluations of Ontario fisheries include Kreutzwiser (1984) - Credit River, Fortin and Evans (1981) - Grand River, Ecologistics with CH2M Hill, 1990 - Bay of Quinte, and Talhelm et al, (1987) - Muskoka-Haliburton. Valuation studies have also been completed for water supply (Fortin and McBean, 1985) and for beach use (Ecologistics, 1990). Not all of these studies have established a link between changes in water quality and changes in value. where they have, conventional water quality parameters have been considered rather than toxics. In the beach use study, valuation results from a demand model are compared to those from a contingent valuation approach.

Other monetary techniques are available in addition to demand curve and contingent value methods. Muller (1985) uses cost of production information including measures of the marginal value product of water to infer the value of water in various commercial/industrial activities for Canada. Standardized damage functions underpin the valuation of flood damage reductions resulting from flood control structures (McBean et al, 1988).

There are as well a number of studies that derive a qualitative evaluation of water quality effects (Gillies et al, 1989; Parkes, 1973; DPA Group, 1987; SPR Associates Ltd, 1986). Among the merits of a qualitative approach are the more modest data requirements, and more importantly, the opportunity to treat high risk/low probability events in a manner that is more consistent with the perceptions of individuals who are exposed to such events. Their response may be based on personal factors such as loss aversion and the lack of personal control. Under such circumstances, it may be unrealistic to use models that attempt to derive a measure of compensation requirement as a valuation of additional risk, when what respondents really want to consider are issues such as mitigation (Kliendorfer and Kunreuther, 1988; Weinstein and Quinn, 1983).

Working within the framework of one's own discipline, it is all too easy to be absorbed by the conceptual and technical challenges of problems as they are perceived and defined within the discipline. In environmental planning work, this perception usually results in an imbalanced characterization of environmental systems and problems. The economist will reduce complex physical, chemical and biological processes into simple one dimensional relationships that lend themselves to the convenience of algebraic manipulation; the engineer will overlook critical socio-economic dimensions that will influence the outcome of a planning solution. The challenge of the proposed project will be to arrive at

a balanced treatment of the water resource-human system so that key linkages are maintained throughout the system without at the same time making the modelling approach unwieldy and ineffective.

3.2 The Computational Framework (DSS)

The potential scope and nature of the tool developed to support valuation of public benefits of water pollution encompasses a wide spectrum of choices. As discussed in the previous section, realistic valuation of the benefits of pollution control must be built upon a reasonable representation of the linkages between the source of a water pollutant and its effect on a public benefit. As illustrated conceptually in Figure 1, these linkages encompass the full spectrum of the bio-physical, social and economic components of the ecosystem. Since the existing tools and data available to describe and quantify these linkages vary greatly in quality and quantity, a computational tool to estimate the benefits of water pollution likely can not consist of only one type of model. At one extreme are complex process models that may provide reasonable estimates for one part of the overall system for some locations. At another extreme is the "best guess" judgement of experts for components of the system in which relatively little work has been done. Additional alternatives include simplified representations of detailed process analyses and statistical models for some linkages.

Upon reviewing the scope of the necessary analysis, we conclude that a critical step in successfully developing and applying the computational tool for benefits assessment will be determining an appropriate mix of approaches and models for the various linkages within the overall computational framework. To permit the framework to be applied to both *ex post* and *ex ante* analyses in a wide variety of locations it must be designed to be flexible so that the best information may be employed where available, yet permit more speculative analyses where detailed data is lacking. At the same time, to remain credible such a system must also provide documentation of the level of uncertainty associated with different analyses and data sources.

The most flexible approach may be to develop the framework along the lines of a spread sheet in which different cells represent individual linkages within the overall benefit valuation system. The linkage represented by a single cell might be expressed as single model or a set of alternative model formulations; for example a simplified process model, categorical threshold model, a link to inputs from a more detailed process model, or perhaps values based on expert judgement.

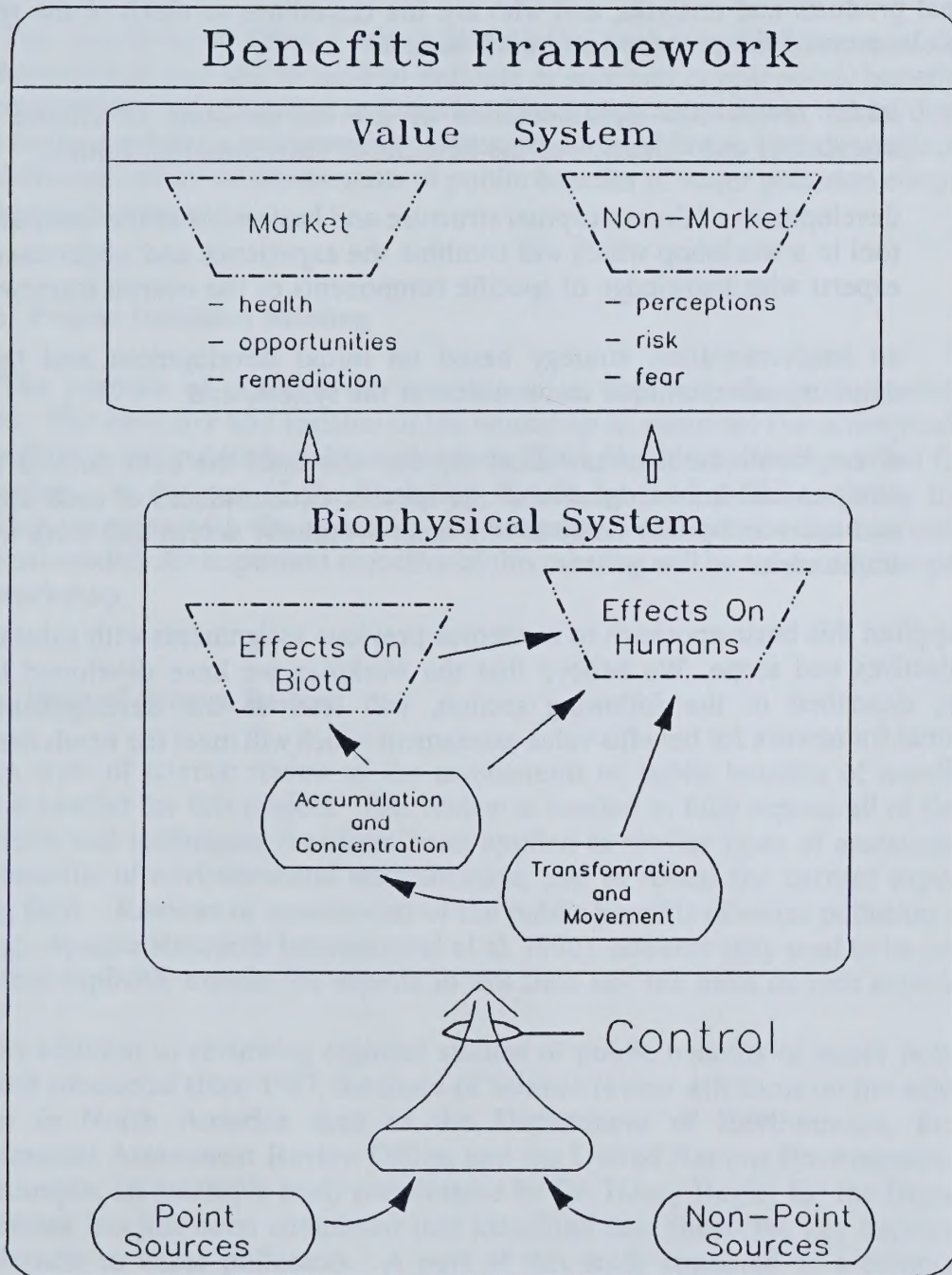


Figure 1: Conceptual Framework

3.3 Approach

The approach we propose for this assignment is to develop the needed computational framework in close consultation with and involvement of ministry staff who ultimately will use the final products and analyses, and who are the custodians of much of the required data. Key elements of the proposed approach include:

- initial review and documentation of the current state of science in the assessment and valuation of the benefits of environmental control,
- development of the conceptual structure and basic rules of the computational tool in a workshop which will combine the experience and understanding of experts with knowledge of specific components of the overall framework,
- an implementation strategy based on initial development and testing - demonstration/critique and revision of the system, and
- direct involvement of technical experts who hold the data needed for the analyses and knowledgeable of the specific circumstances of each area, and managers and policy analysts who must eventually accept and work with the framework.

We have applied this basic approach to numerous previous assignments with substantively similar objectives and scope. We believe that the workplan we have developed for this assignment, described in the following section, will lead to the development of a computational framework for benefits value assessment which will meet the needs described in the RFP.

4.0 Workplan

PHASE I: Conceptual Model of Linkages Between Water Pollution and Public Benefits and Values

The objectives of Phase I are to initiate the project and to construct the generic computational tool that will be used to evaluate *ex ante* and *ex post* public benefits of water pollution control at selected sites in Ontario. The computational tool will be developed by experts in the workshop environment. Other products of Phase I of the project will be a State of Science review of assessments of public benefits of water pollution control, and an interim project report.

Task 1: Project Initiation Meeting

The purpose of this two day meeting is to fine tune the project workplan and schedule. The structure and logistics of the workshop to construct the conceptual model of water pollution and public benefits and values (Task 4) will be developed and finalized at this meeting. A dry run of the workshop should be held at this meeting in order to familiarize everyone with the approach and techniques that will be used to construct the conceptual model. An important objective of this meeting will be to identify the participants of the workshop.

Task 2: State of Science Review

A state of science review of the assessments of public benefits of water pollution control is needed for this project. This review is needed to fully expose all of the relevant information and techniques that have been applied to similar types of assessments of the public benefits of environmental rehabilitation, and to reveal the current experts in this evolving field. Reviews of assessments of the public benefits of water pollution control do exist (e.g., Apogee Research International et al. 1990), however they tend to be too regional and do not explicitly expose the experts in this field nor the most current experience.

In addition to reviewing regional studies of public benefits of water pollution that have been conducted since 1987, the State of Science review will focus on the work of other agencies in North America such as the Department of Environment, the Federal Environmental Assessment Review Office, and the United Nations Environment Program. As an example, an extensive study coordinated by Dr. Henry Regier for the Department of Environment has just been completed that identified and linked the key impaired uses of Lake Ontario to water pollutants. A part of this study consisted of a compilation and evaluation of more than 500 references on this subject. The reference set from this study needs to be reviewed as other similar literature from other areas of North America and from Europe. The State of Science review will also serve to suggest potential participants to the design workshop.

Task 3: Workshop Background Report

The purpose of the background report is to introduce the invited workshop participants to the project and to inform them of their roles at the workshop. Portions of the State of Science review will be included to help orient the participants to the project. A draft conceptual model of the links between water pollutants, and human benefits and values will also be included in the background report. The draft model will act as a "strawman" to stimulate thought amongst the participants prior to the workshop. The background report will contain the logistics for the workshop and will be distributed to participants two weeks before the workshop.

Task 4: Conceptual Model Design Workshop

A computational tool that links water pollutants to human uses and benefits, and permits assessment of the value of the benefits of associated water pollution control can not be constructed effectively in isolation by a few experts from one or two related disciplines. A tool of this complexity, if it is to be used to provide credible assessments of the public benefits of water pollution control in Ontario, requires the insight of many people expert on the water pollution abatement programs of RAP and MISA, water quality, aquatic ecology, environmental economics, epidemiology, risk and uncertainty assessment, and environmental policy.

We propose to convene a 3 day workshop in which experts in the areas described above will develop a conceptual model of current understanding of the linkages between certain water pollutants in Ontario and human uses and benefits. The "strawman" model of the background report will provide the starting point of workshop discussions. The purpose of the model is provide the platform for formal assimilation of current understanding of the linkages between the key water pollutants and the affected humans uses and values. The model will form the basis of the generic computational tool that ultimately will be used to conduct the *ex ante* and *ex post* analyses of public benefits of water pollution control programs of the Ministry of Environment.

The participants will identify the important pollutants of each study area and the linkages between the pollutants, water quality, and human uses of the areas. These linkages represent the biophysical system of Figure 1. It is anticipated that the linkages will take the form of existing models (e.g., morphoedaphic index, hydrodynamic models), statistical and mathematical relationships, and in certain cases, expert judgement.

The current methods to value the public benefits of pollution control in the study sites will be identified and consolidated for each site. The workshop will focus on public benefits that are defined as *marketable*: those which are manifest as decreases in costs to the public, or increases in productivity, and *non marketable*: welfare benefits associated with perceptions of human and ecosystem health (Figure 1). Current data and techniques for valuating these less tangible benefits (e.g., contingent valuation) at the study sites will be identified.

Where models or mathematical relationships are absent for a linkage between a pollutant and the value of a benefit, the participants will develop strategies to describe the missing links with existing data or from expert judgement alone. Information and data identified at the workshop will also be used to calibrate the generic computational tool to the different study areas in Phase II of the project.

It is anticipated that the 21 study sites can be grouped either by pollution type(s) by human uses and benefits or by other attributes (e.g., degree of urban development). The potential for grouping the sites will be assessed at the workshop. A grouping strategy will ease the effort needed to construct and calibrate the computational tool to the study sites. If a grouping strategy is agreed to at the workshop the stratification should be developed in view of the five sites the client has slated for the *ex ante* analyses of public benefits. Depending on the criteria used in the classification, it will be advantageous ensure that each class of sites be represented by a site that undergoes *ex ante* analyses.

The workshop will identify the study sites for which the links between pollutants and human uses and benefits are best understood. These sites will become candidate test sites for purposes of testing the generic computational tool. Real or simulated data and the strategy with which to test the generic tool (Task 7) will be identified at the workshop.

Task 5: Design Report and Client Meeting

A brief report on the results of the workshop will be prepared shortly after the workshop. The report will carry the background report forward and will document the conceptual model/tool that is articulated at the workshop. The report will be presented and discussed at a meeting with the client.

Task 6: Model Implementation

This task will involve extensive information synthesis and computer programming. The generic tool that will form the basis for the *ex ante* and *ex post* analyses at the study sites will be constructed from the conceptual model that emanates from the model workshop. All of the mathematical and statistical relationships and expert judgement that are identified at the workshop will be integrated into the generic tool. It is anticipated that the tool will likely take the form of a spread sheet that will link/consolidate the existing biophysical models and statistical relationships that are identified at the workshop. A spread sheet is an example of the type of tool base that provides the analytical flexibility that will be needed in the *ex ante* and *ex post* analyses of public benefits of water pollution control.

Task 7: Preliminary Analyses and Testing

The purpose of this task is to test the generic tool with test data that is identified at the workshop in order to evaluate the operation of the tool, and to determine components

of the tool that require further refinement. Scenarios of different levels of water pollution controls at different study sites and the effects on human uses and benefits will be assessed to determine the degree of realism that the tool captures.

Task 8: Interim Report

The interim report will review the results of Phase I of the project. Ideally, the report will document the generic computational tool and the results of the preliminary test analyses of *ex ante* and *ex post* public benefits of water pollution control at the test sites. The document will report on the current strengths of the computational tool and the requirements for further development. The report would be submitted to the client for review in preparation for the project review meeting of Task 9. Alternately, to meet timing requirements for this report, this document will be prepared earlier in the project. (see also section 6.3, schedule).

Task 9: Review Meeting

This meeting will be held with the client. The purpose of this meeting is to review the interim report and finalize plans for Phase II of the project.

PHASE II: Database Development and Calibration of Generic Tool

The objective of Phase II is twofold: to construct a database that can be used to derive empiric estimates of *ex ante* and *ex post* incremental benefits and associated values for specific pollution control and abatement levels for industrial and municipal wastewater dischargers; and to calibrate the generic tool developed at the workshop to the 21 study sites. Information used in construction of the data base will be used in the calibration.

Task 10: Data Acquisition and Calibration

There exist in ministerial and other agency data banks, data which can be used to develop empiric estimates of the effects of pollution control measures on human uses and associated values at the study sites. These data will be used to construct empiric estimates of *ex ante* and *ex post* public benefits of water pollution control at selected study sites. These data and derived empiric relationships will be used in the calibration of the computational tool to the study sites

To facilitate data acquisition for the analyses, we will use a generalized data format to organize and keep track of the data that is obtained for the different study sites. The form will be a matrix of pollutants by human uses. Each completed cell will be either a numeric value, an equation, an algorithm, or an expert estimate, and will represent the relationship between pollutant and human use.

The RAP and study site contacts who attended the model workshop will be sent the form for completion. The RAP and study site contacts will fill in as much of the cells of the form as possible and then return the form to the project team. It is anticipated that the client will assist in the location and acquisition of data that are located in ministerial databases.

The computational tool will be calibrated to the study sites to the degree the acquired data permit. Our purpose here is to operationalize the computational tool as much as possible in preparation for the Demonstration Workshop of Task 11.

Task 11: Demonstration Workshop

The purpose of this 2-3 day workshop is to demonstrate the application of the computational tool to the different study sites. Participants of this workshop will include the RAP and study site contacts that provided the completed data forms. The calibrated tool will be tested by the RAP and study site contacts at the workshop. Preliminary analyses with the tool as calibrated to the different sites will be conducted to determine deficiencies in linkages between the pollutants and human benefits, and deficiencies in the ability to value the benefits.

It is important that the tool be applied to many sites in this workshop despite possible data deficiencies at some sites. Any deficiencies in the linkages between a pollutant and a human benefit, or in the valuation of a benefit that impedes the application of the tool to a particular study site will be addressed at the workshop. Data, a mathematical/statistical relationship, or expert judgement that is needed to complete a deficient link will be identified at the workshop. These final modifications will be incorporated into the calibrated computational tools.

PHASE III: Analyses of *Ex ante* and *Ex post* Benefits Assessments at Selected Sites

The objective of Phase III of the project is to conduct the *ex ante* and *ex post* analyses of the effects of water pollution control at the study sites with the calibrated tool. The *ex ante* and *ex post* analyses that will be conducted in Phase III will be prescribed by the client.

Task 12: Meeting to Identify Sites and Scenarios for Analyses

The purpose of this meeting is to determine the analyses that are to be conducted with the computational tool. The results of the Model Calibration and Demonstration Workshop will be reviewed. The final selection of analyses will depend in part on the development of the tool for each study site.

Task 13: *Ex ante* and *Ex post* Analyses

The final analyses and scenarios that are determined in Task 12 will be conducted by the project team.

Task 14: Draft Report, Documentation, and Follow-up

This document will update the interim report, and will report on the entire project. It will contain the results of all the analyses conducted in Phase III, and will contain the revised computational tool from Phase II. The draft report will provide the complete documentation for the computational tool.

We have developed a workplan for this project that will develop and test a computational tool that will enable assessment of the benefits of water pollution control. We have devoted considerable time in the workplan to the testing and tuning of the tool and believe that upon completion no post project follow-up will be necessary.

Should it be desired we are most willing to provide follow-up support. Three types of follow-up support that commonly occur are: 1) further scheduled advice and instruction on the use of the framework; provision of services for additional development of analysis; on-going support on an as needed basis. We judge that the details of follow-up support if desired should be developed at the end of Phase III in conjunction with the draft report.

Task 15: Draft Report Review Meeting

The project team will meet with the client to discuss the report and to discuss post-project follow-up support that may be desired. Changes to the draft report will be identified at this meeting.

Task 16: Final Report

The final report will incorporate the changes to the draft report.

Task 17: Project Status Reports and Meetings

The RFP states that monthly meetings and brief progress reports are required. The meetings and reports scheduled in the workplan which coincide with milestones of the project should fulfil much of this requirement. Additional meetings and reports are anticipated and will be scheduled as needed during the initiation meeting for the project.

Alternative Approach to Phases II and III

In Phases II and III the project team is responsible for data collection and calibration of the computational tool to the different study sites. This means that at the end of the project only the project team will have the depth of understanding of the applying the computational tool that comes with substantive hands on experience.

An alternative approach to Phases II and III which should be considered is to have an employee from the Ministry of Environment (MOE) work closely with the project team starting in Phase II. In this way the MOE representative would become trained to operate the computational tool through the calibration process and would be able to work with the RAP and study site contacts to calibrate the tool to the different study sites. This alternative in Phase III will be addressed at the initiation meeting for the project.

Mr. Gault is currently acting as the Chairman and President for the Lac Seul Advisory Committee, a body composed of representatives from the local municipalities, groups in the area. The committee is charged with advising the Ministry of Natural Resources on issues relating to the implementation of the Lac Seul Management Plan. Mr. Gault was also responsible for leading a project analysis team in the development of a multi-scale assessment model for implementation with the Great Lakes and St. Lawrence Program, a large scale policy analysis model of the Canadian economy.

Mr. Gault has also worked extensively on various projects for Ontario Hydro, employing systems analysis and modelling to design, monitor, optimize and evaluate the effects of various and complex water resources. He manages the use of the DISTRICK model and has been applied to forecasting the effects of the Drought and Flooding Thruflow Project. Consulting services for the regional communities. Mr. Gault also participated in the development of the spatial analysis models that are being used to evaluate the potential future and historical effects of the Bruce II Nuclear Generating Station on Lake Huron.

Mr. Gault is currently acting as the Chairman and President for the Lac Seul Advisory Committee, a body composed of representatives from the local municipalities, groups in the area. The committee is charged with advising the Ministry of Natural Resources on issues relating to the implementation of the Lac Seul Management Plan. Mr. Gault was also responsible for leading a project analysis team in the development of a multi-scale assessment model for implementation with the Great Lakes and St. Lawrence Program, a large scale policy analysis model of the Canadian economy.

Dr. Donald McIsaac

Dr. McIsaac is a senior scientist with ESSA Ltd., having spent the project on research and diverse hydrological and environmental of the effects of various activities on aquatic environments. While working as a senior aquatic scientist for Environment Canada, Dr. McIsaac was responsible for the design and implementation of water quality monitoring programs in southern New Brunswick and Labrador. These programs were initiated to develop water quality objectives for these remote areas. Dr. McIsaac's current work

Benefits Assessment of Pollution Control Proposal to OMOE

Document ID: 100-100000-100000-100000-100000-100000

Alternative 1: No Action (Baseline)

The baseline scenario assumes that the current level of pollution remains unchanged. This scenario is used to compare the benefits of the proposed pollution control measures. The baseline scenario is based on the current level of pollution, which is estimated to be 100 units per year.

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Table 1: Baseline Scenario Summary

The baseline scenario is based on the current level of pollution, which is estimated to be 100 units per year. This scenario is used to compare the benefits of the proposed pollution control measures. The baseline scenario is based on the current level of pollution, which is estimated to be 100 units per year.

Table 2: Pollution Control Measures

The pollution control measures are based on the current level of pollution, which is estimated to be 100 units per year.

Table 3: Pollution Control Measures Summary

The pollution control measures are based on the current level of pollution, which is estimated to be 100 units per year. This scenario is used to compare the benefits of the proposed pollution control measures. The pollution control measures are based on the current level of pollution, which is estimated to be 100 units per year.

5.0 Project Team

We have selected a project team that comprises expertise in water pollution studies, aquatic ecology, and environmental economics and policy. Our project team has a combination of expertise and experience in the development of similar tools that is needed to undertake will the smooth and timely execution of all aspects of the project.

Mr. Lorne Greig

Mr. Greig, a senior systems ecologist and managing partner of ESSA's Toronto office, brings to this project extensive experience in systems analysis, ecological modelling and facilitation of resource management workshops. Mr Greig will manage this project. Completed assignments include the development of a nutrient model for the Bay of Quinte RAP committee which is being used to assess the effects of phosphorus loadings to the Bay of Quinte ecosystem, and a review of the Strategic Plan for Ontario Fisheries for the Ontario Ministry of Natural Resources.

Mr. Greig has also worked extensively on numerous projects for Ontario Hydro, employing systems analysis and simulation modelling to design monitoring programs to assess the effects of nuclear and hydraulic power generation. He managed the team that designed the DARPICK model that has been applied to assessing the effects of the Darlington and Pickering Nuclear Power Generating Stations on the aquatic environment. Mr. Greig also participated in the development of the system of ecological models that are being used to analyze the potential aquatic and terrestrial effects of the Bruce B Nuclear Generating Station on Lake Huron.

Mr. Greig is currently acting as the Chairman and facilitator for the Lac Seul Advisory Committee, a body composed of representatives from the major stakeholder groups on Lac Seul. The committee is charged with advising the Ministry of Natural Resources on issues relating to the implementation of the Lac Seul Management Plan. Mr. Greig was also responsible for leading a project analysis team in the development of a residuals estimation model for incorporation into the Socio-Economic Resource Framework, a large scale policy analysis model of the Canadian economy.

Dr. Donald Meisner

Dr. Meisner, a systems ecologist with ESSA Ltd., brings to this project an extensive and diverse background in assessments of the effects of human activities on aquatic environments. While working as a water resource scientist for Environment Canada, Dr. Meisner was responsible for the design and implementation of water quality monitoring programs in northern New Brunswick and Labrador. These programs were initiated to develop water quality objectives for these remote areas. Dr. Meisner's doctoral work

involved an extensive assessment of the potential effects of climatic warming on coldwater fish habitat in streams in southern Ontario. During his graduate work, he also played a major role in a large-scale assessment of the potential effects of climatic warming on fishes of the Great Lakes.

His professional experience at ESSA includes an assessment of the effects of the thermal effluent from the Bruce B Nuclear Station on smallmouth bass communities, the revision of the Class EA for Shoreline and Riverbank Improvements of Ontario Hydro, and the development of a management protocol for the Integrated Management of Sea Lamprey in the Great Lakes basin. Dr. Meisner has just completed the first Phase of a project for the Bay of Quinte RAP committee on the development of a model of the trophic interactions of the Quinte system. This model when completed will be used by the RAP committee to increase understanding of the biophysical factors that control algal biomass in this Area of Concern. Dr. Meisner's expertise in systems analysis and ecological modelling will be very useful in this project.

Dr. Peter Morrison

Dr. Morrison combines a solid background in ecological science with a detailed understanding of the techniques for social and economic policy analysis. His graduate work focused on the ecological and economic consequences of introducing two new insect species to North America. In his work with the Forest Economics and Policy Analysis Project at the University of British Columbia, he helped develop computer-based tools for predicting the economic consequences of changes in national and provincial forest policy. As a professor at Trent University, Dr. Morrison developed and taught popular courses in environmental impact assessment, forest ecology and management, natural resource theory and management, and simulation modelling. These courses drew on his training in ecology and economics, and included topics such as water resource management issues, economic analysis of environmental regulations, and valuation of non-marketed benefits and costs.

Since joining ESSA, Dr. Morrison has applied his expertise to several projects related to environmental and natural resource economics. For example, he participated in a workshop reviewing "natural capital" approaches for assessing environmental degradation, and he developed an economic critique of computerized tools for predicting the impacts of controlling gases that contribute to the "greenhouse effect". He recently appeared as an expert witness before the Ontario Environmental Assessment Board which is reviewing the environmental effects of timber management on Crown land in Ontario. He gave testimony on the economic principles of forest management and discussed the problems of valuing non-marketed ecological benefits.

Dr. Morrison's major focus at ESSA has been on the development of computerized systems for natural resource management and environmental assessment, in particular expert systems for screening the environmental impacts of projects. Screening systems have been or are being developed for the Airports Authority Group (Transport Canada), the Department of National Defence, the Canadian Parks Service (Environment Canada), Waterways Development (Transport Canada), Public Works Canada, and Indian and

Northern Affairs Canada. He has played a lead role in the knowledge engineering for these projects, interacting closely with his clients to build up the necessary databases for the systems.

Dr. Henry A. Regier

Dr. Regier will act as project advisor. He will help scope the project, and will help develop the framework for the computational tool. Dr. Regier will assist in the interpretation of the results of the *ex ante* and *ex post* analyses of the public benefits of water pollution control in Ontario.

A University of Toronto faculty member since 1966, Dr. Regier is a professor in the Department of Zoology and Director of the Institute for Environmental Studies. His expertise lies in the rehabilitation and sustainable use of nature's resources, with an emphasis on fisheries. Since 1954 he has worked on a recurring basis on the streams and lake waters of the Great Lakes Basin and beyond.

Dr. Regier's broad experience in natural resource studies has been honed through years of research and teaching. His accomplishments are well documented and include appointments to the Great Lakes Fishery Commission, Ontario Society for Environmental Management, International Association for Great Lakes Research, International Joint Commission, UNESCO's Man and the Biosphere Program, and the International Institute of Applied Systems Analysis. Dr. Regier's professional affiliations are supplemented by the publication of over 200 papers.

Dr. Regier's expertise is vast and well developed. He has investigated the impacts of climate warming on aquatic resources in the Great Lakes and elsewhere, the rehabilitation of degraded aquatic systems and their related fish communities, fish population dynamics, and the ecology of exploited freshwater fish communities. Dr. Regier's current focus is on methodologies with which to assess the health of aquatic ecosystems in the Great Lakes basin.

Mr. Michael Fortin

Mr. Fortin specializes in the application of economic principles to the analysis of environmental and resource management problems. He has been involved in environmental economics consulting for the last ten years and has wide experience in policy analysis, program planning and evaluation, applied environmental economic research and the development of user pay strategies.

Mr Fortin has used his expertise in environmental economics in a wide range of natural resource related projects. He has participated in many studies that have focused on waste and wastewater, watershed planning, resource evaluation and assessment, program planning and evaluation, agriculture and the environment, economic development, and applied research. Mr. Fortin's skills also include economic modelling and linear programming. Mr. Fortin's skills in environmental economics and natural resource planning and evaluation will be a valuable addition to this project.

The following table provides a summary of the benefits of the proposed pollution control measures. The benefits are categorized into three main areas: environmental, health, and economic. The environmental benefits include improved air quality, reduced greenhouse gas emissions, and protection of water resources. The health benefits include reduced respiratory and cardiovascular disease, reduced cancer risk, and improved overall public health. The economic benefits include increased productivity, reduced healthcare costs, and increased property values. The table also includes a section for the costs of the measures, which are estimated to be \$10 million per year. The net benefits of the measures are estimated to be \$15 million per year.

Category	Benefit	Estimated Value (\$/Year)
Environmental	Improved air quality	5,000,000
	Reduced greenhouse gas emissions	2,000,000
	Protection of water resources	1,000,000
	Reduced noise levels	1,000,000
Health	Reduced respiratory disease	3,000,000
	Reduced cardiovascular disease	2,000,000
	Reduced cancer risk	1,000,000
	Improved overall public health	1,000,000
Economic	Increased productivity	2,000,000
	Increased property values	1,000,000
Costs of measures		(10,000,000)
Net benefits		15,000,000

The following table provides a summary of the costs of the proposed pollution control measures. The costs are categorized into three main areas: capital costs, operating costs, and maintenance costs. The capital costs include the cost of purchasing and installing the equipment. The operating costs include the cost of electricity, fuel, and other resources. The maintenance costs include the cost of repairs and replacement of parts. The total costs of the measures are estimated to be \$10 million per year.

Category	Cost	Estimated Value (\$/Year)
Capital costs	Purchasing and installing equipment	5,000,000
	Other capital costs	1,000,000
Operating costs	Electricity, fuel, and other resources	3,000,000
	Other operating costs	1,000,000
Maintenance costs	Repairs and replacement of parts	1,000,000
	Other maintenance costs	1,000,000
Total costs		10,000,000

6.0 Proposed Budget and Schedule

6.1 Budget

The estimated effort needed to develop, test, apply and document the computational framework for benefits assessment as described in the workplan (Section 4.0) is 335 days. The estimated total cost to conduct the project is \$ 180,405 of which \$163,469 is allocated for fees to conduct the work and \$ 16,757 is allocated to project expenses. Table 1 provides a detailed breakdown of this estimate by tasks and resources.

This budget includes all fees and expenses to be incurred by the project team in conducting the work outlined in the workplan in Section 4.0 of this proposal. The budget does not include any costs to be incurred by participants invited to attend the project workshops. The budget also reflects the following assumptions

- the computational framework will be developed to run on standard IBM ^T compatible 286/386 based micro-computers,
- charges, if any, for mainframe/service bureau computer systems which the ministry may employ for database access will not be attributable to the project budget,
- all project workshops will be held in the Toronto area and will not require accommodation for the project team, and
- all project meetings will be held in the Toronto vicinity, likely either in the ministry's offices or a the ESSA offices in Richmond Hill.

6.2 Deliverables

The following deliverables are provided for in the project budget

- 1) a functional, tested, implementation of the calculational framework to be installed on ministry micro-computers,
- 2) the interim report specified in the RFP,
- 3) two workshops with ministry staff which will serve both to help develop and critique the framework but also to expose a significant number of staff to the project approach and results,
- 4) completed ex post and ex anti analyses as agreed during the project planning meetings,

- 5) project draft and final reports documenting the structure of the computational framework and analysis results,
- 6) documentation on how to use the framework, recommendations for post development support strategy, and
- 7) monthly project status reports and meetings.

6.3 Project Schedule

As illustrated in Table 1 we estimate that the requirements described in the RFP requires a substantial level of effort to yield the project deliverables. The project schedule necessary to complete the assignment by March 31, 1992 is ambitious (Figure 2). While it is feasible to undertake the assignment on this schedule, there is little or no slack in the schedule and consequently delays in initiating project tasks (e.g. scheduling workshops or key project meetings) may adversely affect timely completion of the project. A key assumption reflected in the schedule is that key staff from the ministry will be available for project consultation when needed. If it is feasible for the ministry to plan for a portion of the work to extend into the next fiscal year, we recommend that it would be prudent to do so. If this is not possible then it should be recognized that for the project to proceed on schedule will take a concerted co-operative effort by both the project team and key ministry staff.

Figure 2 illustrates two potential windows (a or b) for producing the interim report described in the RFP. The first window meets the ministry's requirement for this report within three months of project initiation. At this stage in the project this report will be able to address the overall design and detailed approach of the calculational framework. Initial implementation and testing will not, however, be completed. The second window (b) in our view provides the additional benefit of being able to include the results of preliminary analyses made during the initial testing phase of the development effort and thus offers the potential of being more complete. Notwithstanding the benefits of the later window, we understand the ministry's specific request for the timing of this report. The alternative is presented here solely for consideration by the ministry's steering committee.

Table 1: Estimated Project Costs.

FEES

	Project Staff -->		Greig \$750	Meisner \$475	Morrison \$525	Fortin \$500	Research		Task Totals
	Daily Rate -->						Regier \$500	Assistant Programmer \$400	
Phase I - Model Development									
Task 1. Planning Meeting.....	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0	10.0 \$5,500
Task 2. State of Science.....	1.0	5.0	3.0	3.0	3.0	3.0	0.0	5.0	17.0 \$8,200
Task 3. Background Document.....	0.5	3.0	2.0	2.0	2.0	2.0	0.0	2.0	9.5 \$4,650
Task 4. Design Workshop.....	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	15.0 \$8,250
Task 5. Design Report.....	3.0	5.0	3.0	3.0	3.0	3.0	0.0	3.0	17.0 \$8,900
Task 6. Model Implementation....	0.0	8.0	0.0	0.0	0.0	4.0	0.0	0.0	47.0 \$19,800
Task 7. Analysis / Testing.....	1.0	5.0	1.0	2.0	1.0	2.0	0.0	5.0	24.0 \$10,650
Task 8. Interim Report.....	1.0	4.0	0.0	2.0	0.0	2.0	0.0	5.0	16.0 \$7,250
Task 9. Review Meeting.....	1.0	1.0	0.0	1.0	0.0	1.0	1.0	0.0	4.0 \$2,225
Phase II - Database Development & Model Calibration									
Task 10. Database & Calibration..	0.0	6.0	0.0	0.0	0.0	6.0	0.0	25.0	47.0 \$19,850
Task 11. Demonstration Workshop..	2.0	2.0	3.0	2.0	3.0	2.0	0.0	2.0	11.0 \$5,825
Phase III - Site Benefits Analysis									
Task 12. Preparation Meeting.....	1.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	3.0 \$1,725
Task 13. Site Analyses.....	0.0	12.0	0.0	12.0	0.0	12.0	0.0	10.0	39.0 \$17,700
Task 14. Draft Report.....	3.0	8.0	0.0	6.0	0.0	6.0	1.0	4.0	28.0 \$13,550
Task 15. Report Review Meeting....	1.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	3.0 \$1,725
Task 16. Final Report.....	2.0	5.0	0.0	3.0	0.0	3.0	0.0	5.0	15.0 \$7,375
Task 17. Status Reports/Meetings..	2.0	3.0	0.0	2.0	0.0	2.0	0.0	0.0	7.0 \$3,925
Project Management.....	22.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.1 \$16,549
Days	45.6	74.0	17.0	55.0	17.0	55.0	7.0	66.0	334.6
Fees	\$34,174	\$35,150	\$8,925	\$27,500	\$8,925	\$27,500	\$3,500	\$26,400	\$163,649
DISBURSEMENTS									
	Units	Cost per Unit	Total Cost						
Travel - ground transportation			\$400						
Living Expenses (ESSA team):	27	\$30	\$810						
Report Production			\$10,637						
Communication			\$4,909						
Total Disbursements			\$16,757	Total Project Costs					
				\$180,405					

**Benefits Assessment of Pollution Control
Proposal to OMOE**

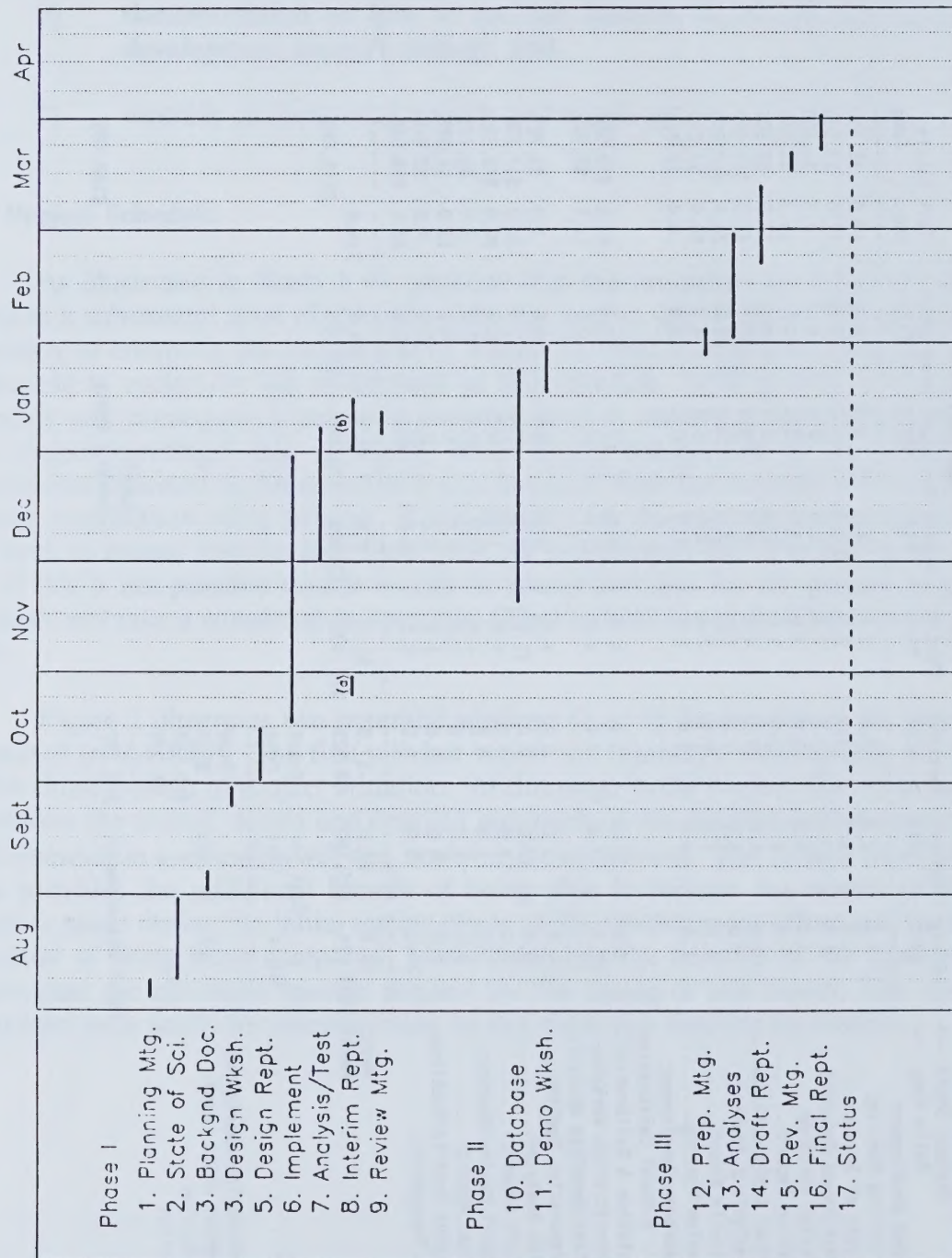


Figure 2: Proposed Project Schedule

6.4 Contract

We have reviewed the general terms and conditions set out in the Ministry's standard agreement and find them generally acceptable. We recommend the following be given due consideration

- 3.1 - page 2: In view of the tight schedule for the project, should substitution of project personnel become necessary to ensure timely completion of the project work, such approval will not be arbitrarily withheld.
- 5.1 - page 3: Although the general nature of the computational framework and analyses are known the details will be determined during the project. It will be necessary to define these final products such that they are consistent with the agreed upon project resources.
- 20. - page 8: A copy of such evaluation, if prepared, should be provided to and discussed with the contractor.

The following table provides a summary of the benefits and costs of the proposed pollution control measures. The benefits are calculated based on the expected reduction in emissions, and the costs are based on the estimated capital and operating expenses.

The benefits of the proposed measures are expected to be realized over a period of 10 years. The costs are expected to be incurred over the same period. The net benefits are calculated as the difference between the benefits and costs.

The following table provides a summary of the benefits and costs of the proposed pollution control measures. The benefits are calculated based on the expected reduction in emissions, and the costs are based on the estimated capital and operating expenses.

The following table provides a summary of the benefits and costs of the proposed pollution control measures. The benefits are calculated based on the expected reduction in emissions, and the costs are based on the estimated capital and operating expenses.

Measure	Benefit (\$/yr)	Cost (\$/yr)	Net Benefit (\$/yr)
1. Installation of air filtration system	100,000	50,000	50,000
2. Implementation of water recycling system	80,000	30,000	50,000
3. Installation of noise abatement measures	60,000	20,000	40,000
4. Implementation of waste management program	40,000	10,000	30,000
5. Installation of energy efficiency measures	20,000	10,000	10,000
Total	300,000	120,000	180,000

7.0 Corporate Experience

ESSA Environmental and Social Systems Analysts Ltd. is a dynamic and innovative research and development firm dedicated to the formation and implementation of creative solutions to environmental problems.

An independent 100% Canadian-owned company, ESSA was incorporated in 1979 by three systems ecologists associated with the Institute of Animal Resource Ecology at the University of British Columbia. ESSA was formed to address a need in the community for instruction and development of techniques on Adaptive Environmental Assessment and Management (AEAM). Since that time, we have successfully branched out into related disciplines concerned with environmental planning, research and management and have completed over 400 projects during the past decade. Our clients range from corporate to government to non-profit organizations with project locations in North and South America, Europe, Southeast Asia and Australia.

ESSA works in close consultation with clients to ensure that the project proceeds in a manner which will result in a product that accurately meets their needs. We apply techniques such as computer simulation, expert systems, mathematical models, database design/management and statistical analysis to projects requiring understanding of scientific information and issues. The company has developed a broad range of skills and applications, including:

- designing, building and testing ecological models and expert systems for use in resource management and environmental assessment;
- facilitating intensive, highly structured workshops to extract and synthesize expert information; and
- quantitative and analytical skills necessary to analyze and synthesize large amounts of information.

ESSA's unique combination of expertise and skills makes it the best company to undertake this project.

The following section lists ESSA projects which we feel are relevant to this project.

Methods Development

ESSA has extensive experience in the development of procedures and methods for dealing with environmental issues and problems, both in Canada and the United States. In the last decade, ESSA has completed over 50 projects oriented towards either research in procedures and methods, or application of these procedures to project assessments. These

projects have incorporated ESSA's skills in a number of areas, including conceptual, mathematical and computer simulation model building, facilitation of multidisciplinary planning workshops, project design, training, and policy analysis.

Project: Cumulative Effects Assessment: Development of a Research Prospectus
Client: Canadian Environmental Assessment Research Council

The purpose of this contract was to scope the issue of cumulative effects and cumulative effects assessment. The resulting product was a report which reviews the history of cumulative effects in Canada and the U.S., develops a framework for characterizing cumulative effects, and offers a set of lessons and recommendations for improving our scientific and institutional ability to identify and assess cumulative impact situations. To accomplish this, ESSA held three workshops across the country in order to access current thinking on cumulative effects from EIA practitioners, academics and senior managers in industry and government. Further, three case studies were analyzed in detail to determine the nature of cumulative effects in each system and how they were assessed. Scientists and managers from a number of key institutions in the United States who are currently concerned with cumulative effects worked with the Canadian research team to ensure that the CEARC study received maximum benefit from work done elsewhere. The results of the study were summarized in the report to CEARC, and have served as a major contribution to CEARC's development of a research prospectus on cumulative effects.

Project: Hamilton Harbour Remedial Action Plan
Client: Ontario Ministry of the Environment, Water Resources Branch

ESSA was contracted by the OMOE to help prepare a monitoring plan for Hamilton Harbour. Prior to this project several government agencies had been conducting independent monitoring programs of the harbour for various parameters of aquatic environmental quality. In many instances effort was being duplicated, and in others key parameters were not being sampled sufficiently. The focus of this project was a workshop, facilitated by ESSA, in which the various monitoring agencies discussed techniques of improving the quality of monitoring via co-operative efforts. Prior to the workshop, ESSA conducted a review of the monitoring and research activities that were taking place in the harbour. This review was used as a focus for the workshop.

Project: Petro-Canada LNG Site Selection
Client: Petro-Canada (with Hatfield Consultants Ltd.)

The site selection method for this project, developed by ESSA, attempted to integrate the environmental, social, economic, and safety dimensions of impact assessment. This integration was done using a risk analysis approach, assigning weights to indicators that represented major potential impacts in the four dimensions for each potential site. Expert judgements of specialists in each of the four dimensions were used to quantify changes to the indicators (ie., number of salmon affected) and to assign weights. The site selection

process was then incorporated into an interactive computer model where changes could be made to the weighting of indicators, as desired by decision-makers, in order to evaluate alternatives.

The selection of Bish Cove, in Douglas Channel, as Petro Canada's western LNG terminus was based on this model. The documentation of the site selection process was a major component of Petro Canada's application to the B.C. government for an energy project certificate. By providing an integrative framework for assimilating and synthesizing the extensive amount of information required for the site evaluation, this study made a significant contribution to the understanding of both scientists and managers.

Project: Transportation of Dangerous Goods
Client: Transportation of Dangerous Goods Study Group, Transport Canada

This project involved designing a framework for the measurement of relative risk to human life, property, and the environment from standard exposures to 25 "dangerous" commodities, including gas and propane. A workshop was held at which consensus was reached on the process to be used in the risk analysis, and the nature and use of the data available to support the needs of the analysis. The framework was formalized in a computer simulation model, which was subsequently demonstrated to Transport Canada researchers at a second formal workshop and at a series of meetings.

Project: Mercury Release in Hydroelectric Reservoirs
Client: Canadian Electrical Association

Project objectives included synthesizing current understanding of the problem of elevated mercury levels in fish living in recently flooded reservoirs, developing methods for predicting the likelihood of occurrence of this problem, and providing guidelines for mitigation and recommendations for further research.

ESSA's approach to meeting these objectives involved four steps. A workshop was held in order to develop a conceptual model of the problem and to select the most appropriate research strategy. The experience of the invited participants was critical to the development of a research plan that was both relevant and feasible. Existing information on the problem was assembled to determine which of the factors identified at the workshop are most prominently associated with elevated mercury concentrations. Subconsultants collected fish, water and sediment samples from eleven reservoirs across Canada to supplement existing data and to provide a more extensive sample of reservoirs for statistical analysis. Microcosm experiments were then conducted to assess which factors are most strongly associated with fish mercury uptake, and most amenable to mitigation. The fourth step involved analysis and synthesis of the data assembled or produced in the first three steps. ESSA combined the existing information and new field data into a multivariate model for predicting the likelihood of occurrence of mercury accumulation problems. The results of the microcosm experiments were compared to field studies performed in larger

enclosures to evaluate their suitability. A final workshop presented the results of the study to both the client and outside experts for their review and critique.

Decision Support Systems (DSS) and Artificial Intelligence

ESSA is an industry leader in the application of the quantitative techniques of systems analysis and modelling to the fields of environmental research, resource management, policy analysis and evaluation. We boast a broad range of computer applications and skills, including:

- designing, building and testing computer simulation models and decision support systems for the analysis of resource management problems, research planning and monitoring of environmental impacts;
- designing, building and testing expert systems for specialized applications in resource and environmental management;
- synthesizing relevant knowledge and data from the scientific community, analyzing it, and presenting the findings to managers and decision makers in a clear and understandable manner; and
- developing sophisticated user friendly model systems that move between menus and which manage large databases.

A decision support system is an interactive, computer-based system designed to aid decision makers in utilizing data, narrative information, analytical tools, and mathematical models in order to address problems. The primary difference between an expert system (i.e. **SCREENER**) and a decision support system (**Lake Trout Management Support System**) is that expert systems are based on qualitative or heuristic reasoning while decision support systems deal with quantitative or algorithmic models. Whereas a decision support system might be used to assess the consequences of a number of different alternatives, an expert system could be used to recommend a preferred alternative.

Project: SCREENER - Environmental Screening System
Clients: Transport Canada, Department of National Defense, Environment Canada - Canadian Parks Service

SCREENER is an expert system designed to evaluate projects for their potential environmental impacts. Screening decisions are made on the basis of existing information about a proposed project and the local environment, and involves determining potential adverse environmental effects, the degree of uncertainty and the usefulness of mitigation measures. The screening results determine the nature and degree of further study and attention that environmental aspects of the proposed project will receive.

This software has been developed for Transport Canada (Coast Guard) and is currently being implemented at all federally run airports in Canada. ESSA is presently

adapting SCREENER for use by the Department of National Defense (DND). This system, which will be called the Computer Aided Environmental Screening for Assessment and Review (CAESAR) system, will have a greatly expanded knowledge base to encompass the broad range of activities undertaken by DND. This project involves implementing the system at four sites across Canada after development and testing of the system at CFB Gagetown.

ESSA has recently completed a contract to develop a version of SCREENER for the Canadian Parks Service, with the following scope: 1) it will be applicable to all national parks in all five Parks Service regions; 2) screening officers will be able to quickly and efficiently carry out screenings for all capital projects within those national parks; and 3) the system will be implemented on IBM AT or compatible computers. The Parks Service system will have the same basic structure of the knowledge base and will have the same method of describing impacts currently used in the Transport Canada screening system.

Project: Bay of Quinte Remedial Action Plan Ecosystem Model
Client: Ontario Ministry of the Environment

ESSA worked with the Ontario Ministry of the Environment to prepare a computer model drawing together the most current information on the Bay of Quinte ecosystem. ESSA ran two workshops and designed a computer model for the RAP addressing water quality in the Bay of Quinte. The first workshop served to bound and scope the problem, after which ESSA designed an ecosystem model for the area. The model was comprised of i) physical, ii) nutrient, iii) toxic chemical, and iv) biota submodels. At a second workshop, the model was used to analyze the effectiveness of proposed remedial actions; a key demonstration being the comparison of the relative effectiveness of biological controls and physical-chemical controls in improving water quality. Deliverables from ESSA included a report on the evaluations of various remedial action options, and a working version of the model.

Project: Bay of Quinte Biotics Interactions Model
Client: Ontario Ministry of the Environment (with LGL Ltd.)

ESSA has just completed its part of the first Phase of a joint project with LGL Ltd. to develop a model of the upper Bay of Quinte Ecosystem for the Bay of Quinte RAP committee. The purpose of the project is to provide the committee with a simulation tool with which they can better understand the factors that are controlling the nuisance algal blooms in the upper Bay of Quinte. Phase I of the project consisted of bioenergetic analyses of the growth and food consumption of the major fish species in the Quinte ecosystem. The purpose of Phase I was to estimate the amount of prey consumption in the Bay from 1972-1989 for comparison with measured prey production. Individual age-structured growth models of the five study species were developed in preparation for Phase II of the project. In Phase II these models will be linked to companion models of the lower trophic levels to provide a model of the entire trophic structure of the upper Bay of Quinte. The completed biotic interactions model will enable simulation of the relative effects of phosphorus and predator/prey interactions on summer algal biomass.

Project: Environmental Monitoring for the Darlington/Pickering NGS
Client: Ontario Hydro

Since 1986 ESSA has led a team of systems analysts, scientists and resource managers in the development and evaluation of a model of the potential environmental effects of large nuclear generating stations. The primary objective of this work was to develop an aquatic effects monitoring plan. Participants from both the proponent agency and regulatory agencies worked together under the guidance of the ESSA team to develop a conceptual model of the aquatic environment, expressed as a series of hypotheses of effect. These hypotheses are being used to guide the development and testing of a simulation model of aquatic effects, and design of post-operational monitoring programs.

ESSA's most recent involvement in this monitoring program resulted in the publication of the report Simulation Analysis of the Aquatic Effects of Pickering and Darlington NGS Using the DARPICK Model. The additional simulation analyses discussed in this report were designed to complement and guide the ongoing environmental effects monitoring program.

Project: Fisheries Planning Overview Evaluation Model (FPOEM)
Client: Canadian Department of Fisheries and Oceans

The objectives of this project were to develop a model of the west coast salmon and roe herring fisheries to assist the Department of Fisheries and Oceans in formulating policies for fleet rationalization. ESSA facilitated over ten meetings with economists, fisheries scientists, and representatives of fishing industry organizations. The group jointly constructed a detailed model of west coast fisheries which permits evaluation of economic policies from three perspectives: fishermen, the federal government, and society as a whole.

Two versions of the model were developed: a user-friendly, microcomputer version which contains a comprehensive economic submodel, but only a simplified representation of fish production biology; and a more complex version on a large, mainframe computer which incorporates an existing detailed model of fish population dynamics and catch per unit effort. The economic model is structured in such a way that it allows fishermen using the model to view alternative policies from their own perspective. By considering three different perspectives of the problem, the model explicitly forces policy analysts to consider potential trade-offs.

To assist the client in communicating its approach to the economic problems facing the west coast fishery, ESSA produced four slide-tape programs which described the nature of the problem, the reasons for constructing and using a model, and the model's structure and results. In addition, a detailed user's guide was written to assist people in constructing scenarios and understanding model output.

During group meetings, output from the simulation model provided the focus of discussions on the validity of the model's assumptions, and the effect of alternative

government policies. These discussions led to expanded data collection and analysis, which improved the credibility and utility of the model's predictions. The Department found the model provided them with the ability to examine a much wider range of options than would have been feasible otherwise. Also, the transparency and flexibility of the model's assumptions encouraged dialogue and cooperation between groups with sometimes conflicting objectives.

Project Title: Management Support System for Lake Trout
Project Client: Ontario Ministry of Natural Resources, Owen Sound District

ESSA designed a computerized Lake Trout Management Support System for the Lake Huron Fisheries Assessment Unit. The system was created to assist managers in assessments of the effects of alternate management options (e.g., changes in sport fishing regulations, lake stocking, etc.) on the population structure of lake trout in lakes under their jurisdiction. This simulation model-based management system is one of the major products of the Lake Trout Synthesis project of the OMNR. By integrating current scientific understanding of population dynamics and the effects of harvesting stress on natural and hatchery-reared lake trout populations across Ontario, managers of OMNR have been provided with a powerful tool with which to easily and effectively explore and compare the effects of different management strategies for lake trout.

Project: Application of Empirical Modelling Approaches to Predicting Acidic Episodes in Streams
Client: U.S. Environmental Protection Agency

ESSA was contracted by the EPA to examine the potential for applying empirical modelling approaches to predicting the extent, severity, and frequency of stream acidic episodes. Two approaches were examined: a regional model for predicting acidic episodes associated with snowmelt events, and concentration-discharge relationships for predicting acidic episodes during both snowmelt and storm events. The data needed to develop and test these models (air temperature, precipitation, deposition, snow pack quantity, discharge, and stream and meltwater chemistry) were acquired from a variety of government agencies and university cooperators. The database was then formatted for statistical and reasonable estimates of the relative severity and frequency of acidic episodes. Statistically significant concentration-discharge relationships were found for all streams and chemical parameters examined, indicating that the technique holds considerable promise. Variation among streams was consistently greatly than within-stream variation among events, indicating that there is consistency in a given stream's chemical response.

Socio-Economic Linkages with the Biosphere

ESSA has completed many projects that have incorporated socio-economic concerns into environmental assessments and evaluations, and quantitative models. Using such vehicles as workshops and model building exercises, ESSA has developed products, including

simulation models, decision support systems, management strategies and environmental assessments, that have linked socio-economic factors with bio-physical processes.

Project: National Residuals Simulation System
Client: Environment Canada and Statistics Canada

ESSA was contracted to examine design options for the development of a National Residuals Simulation System (NRSS), intended to assist in the articulation of scenarios of future residuals generation in Canada. ESSA's responsibilities included the development of a design for a NRSS that is responsive to the needs of Environment Canada and that is linked to Canadian socio-economic and resource management concerns. This linkage was explicitly accounted for by designing the NRSS model so that it was compatible with the Socio-Economic Resource Framework (SERF), a decision support system currently under development within Statistics Canada. ESSA was to develop a unified conceptual framework to coordinate the data and activities of Environment Canada departments concerned with various industrial sectors, media of release, and residual types. Appropriate databases were selected from agencies, as needed, to match data analysis and strategic planning requirements.

Design of the NRSS system was accomplished through an intensive three day workshop attended by experts from Environment Canada and Statistics Canada, with some additional expertise from industry and the provinces. The workshop first defined the scope of the NRSS, and then focused on establishing a framework to link the production of residuals to demography, consumer lifestyles, effects on health, industrial activity, and production. ESSA produced a report based on the results of the workshop and the technical meetings. This report was used as a planning document for the implementation, application, and general communication of these results.

Project: Mississippi - Social Impact Assessment of Nuclear Waste Disposal
Client: Mississippi Department of Energy and Transportation

Richton, Mississippi was selected as one of the possible sites for a high level nuclear waste repository in the U.S. ESSA and the Social Impact Assessment Centre (in New York) were asked to design the framework for a socio-economic impact study. Two workshops were held with technical experts to help the consultants become familiar with the range of major issues concerning siting. Between the workshops, an integrative impact assessment model was developed for projecting changes in demographics, economic conditions, etc. The model also included mapping various components of the socio-economic system onto the main pattern of assessment steps. Although the model requires further refinement, it is a useful starting point for planning a detailed assessment.

Project: Mathematical and Simulation Models in Environmental Impact Assessment
Client: Federal Environmental Assessment and Review Office

ESSA was contracted to provide the Canadian Environmental Assessment Research Council with a set of research recommendations regarding the use of quantitative models in environmental impact assessment. While models have been used to address many environmental issues, ESSA focused its study on the use of models in five subject areas of specific interest to CEARC: social impact assessment, biophysical impact assessment, toxic chemical assessment, technical risk assessment, and health risk assessment.

The approach taken by the study team encompassed a literature review of the most advanced developments in modelling applications, an in-depth review of pertinent case studies, preparation of a working report, a workshop at which the working report and the issues raised in it were discussed by experts in the field, and preparation of a final report.

Management Plans and Strategies

ESSA has produced many plans, strategies and recommendations for ecosystem management. These products draw heavily on the AEAM (Adaptive Environmental Assessment and Management) modelling approach; one which makes use of a diverse array of expertise and information and moulds it into a set of comprehensive strategies to address, evaluate, and manage the environmental issues of concern.

Project: Effects Monitoring For Timber Management Guidelines
Client: Ontario Ministry Of Natural Resources (OMNR)

The OMNR is committed to develop, as part of the Timber Management Class Environmental Assessment, a program of environmental monitoring to assess the effectiveness of its guidelines in protecting other resource values in the conduct of timber management activities. ESSA was contracted to develop the monitoring program for assessing those guidelines already in existence (ie., tourism, fish and fish habitat, and moose and moose habitat). ESSA facilitated a series of workshops and technical meetings to focus the collective knowledge and varied perspectives of forestry, wildlife, and fishery managers, research scientists, and other affected groups into a simulation model of the range of possible interactions between forest/timber management actions and fish, moose, and tourism values. This model provided a focus for a rigorous and structured evaluation of the guidelines proposed by the Ministry, resulting in specific recommendations for effects monitoring needs. These recommendations included both the design of the required program and estimation of resources required for its completion. The results of this project have now become a reality, with effects monitoring programs now in place for the tourism, fish habitat and water quality, and moose habitat guidelines.

Project: Upper Great Lakes Connecting Channels Study
Client: Upper Great Lakes Connecting Channels (UGLCC) Management Committee

As part of the planning process for a three-year, multi-agency study of environmental pollution problems in the Upper Great Lakes Connecting Channels, ESSA conducted a research planning workshop for technical and managerial level representatives from the five Canadian and five U.S. agencies involved in the study. Working groups discussed the current level of understanding of the contaminants issues, and how best to direct future research efforts.

A conceptual model based on an empirical mass balance approach was developed and used at the workshop as a means of integrating the major research activities of the study into an overall strategy designed to expedite the UGLCC study goals. This strategy used synoptic survey methods to characterize the system in its first year, followed by more intensive sampling methods in the second year. Finally, these results are being integrated and strategies for long-term monitoring will be recommended.

In addition to the long term strategy, a detailed action plan for the first four months was created to address concerns and issues requiring immediate resolution. These included selection of parameters (ie., contaminants) to measure, review of existing information, development of a general study plan, and establishment of quality assurance and quality control standards for data collection and analysis.

Workshop Facilitation

ESSA has planned and facilitated hundreds of workshops. The experience gained in these workshops has provided ESSA personnel with a refined set of techniques and a keen understanding of the problems and pitfalls with meetings and workshops. ESSA's experience ranges from highly technical scientific workshops dealing with environmental problems to issue-oriented workshops to facilitate public involvement in community based planning.

ESSA workshops strive to:

- bring the right collection of people together;
- direct collective effort towards clearly defined objectives;
- create a forum to foster interaction between all stakeholders; and
- produce products which carry the benefits to wider audiences.

Successful workshops require careful planning, masterful orchestration of the workshop agenda, careful recording of ideas that arise during the workshop, and timely reporting. ESSA prefers to work closely with the client in all aspects of the workshop. For most workshops, ESSA recommends a scoping meeting to review objectives, plan the agenda, discuss the subject matter, select workshop participants, and assign responsibilities. ESSA facilitators are highly trained and experienced at leading plenary and small group sessions and at bringing the workshop to a successful conclusion. The strong systems perspective and scientific experience of ESSA's facilitators allow them to quickly group

complex problems and determine which issues are most important. Another major aspect of ESSA's success in facilitating workshops is the ability to record and synthesize ideas for presentation at the end of the workshop. To ensure that the momentum and consensus generated by a workshop are not lost, ESSA recommends that a workshop report be produced and distributed in a timely fashion.

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Benefits Assessment of Pollution Control Proposal to OMOE

The purpose of this assessment is to provide a clear and concise summary of the benefits of the proposed pollution control measures to the OMOE. The assessment is based on a review of the literature and a consultation with the OMOE staff. The assessment is organized into three main sections: a description of the problem, a description of the proposed measures, and a description of the benefits of the proposed measures. The assessment is intended to provide a clear and concise summary of the benefits of the proposed measures to the OMOE.

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Executive Summary

The assessment is organized into three main sections: a description of the problem, a description of the proposed measures, and a description of the benefits of the proposed measures. The assessment is intended to provide a clear and concise summary of the benefits of the proposed measures to the OMOE.

ESSA's objectives are to:

- 1. Bring the right parties together
- 2. Develop a common vision and shared understanding
- 3. Create a framework for future interaction between all stakeholders and
- 4. Produce products which carry the benefits to wider audiences

The assessment is organized into three main sections: a description of the problem, a description of the proposed measures, and a description of the benefits of the proposed measures. The assessment is intended to provide a clear and concise summary of the benefits of the proposed measures to the OMOE.

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Appendix 1: Resumes

